An ex rcise apparatus and a brake mechanism th ref r

- The present invention relates to an exercise apparatus, preferably portable and preferably for rehabilitative use by a person in a sitting, reclining or lying position for rehabilitation purposes.

An exercise apparatus of this type is known from US patent No. 4,946,162. Two hydraulic cylinders interconnected over an adjustable needle valve are connected to two foot pedals, respectively. A person sitting in a chair exercises by alternatingly depressing each hydraulic cylinder, the resistance against the compression of the cylinders and thus the exercise intensity being varied by adjusting the needle valve.

GB 2 347 873 discloses a rehabilitative exercise apparatus for exercising legs of a bedridden patient where a combination of linear movement (bending the knee) and rotational movement (bending the ankle) is utilised, a variable braking of the linear movement being utilised to vary the force necessary to perform the linear movement.

It has been shown that it is important that as many muscle groups and joints as possible be exercised against a resistance that can be varied such that a development programme for the ongoing exercise may be implemented.

A main object of the present invention is to provide an exercise apparatus whereby at least two different groups of muscles and at least two different joints may be exercised at the same time on the same apparatus with the intensity of the exercise for all muscles and joints involved may be varied.

According to the invention, this object is achieved by the apparatus comprising

- a housing comprising an interior compartment communicating with the surroundings through one or more apertures, preferably slits in said housing
- mechanical activation means for being activated by a limb portion of a person, for instance a foot, a hand , a knee or an elbow of said person, said activation means extending from the interior of said compartment to the surroundings through said one or more apertures,
- first braking or resistance means for exerting a first resistance against a first force applied to said activation means by said limb portion and arranged in said compartment and connected to said activation means, and

- at least one second braking or resistance means for exerting at least one second resistance against at least one second force applied to said activation means by said limb portion and arranged in said compartment and connected to said activation means.

Preferably, the exercise apparatus further comprises first varying means for varying the magnitude of said first resistance, and second varying means for varying the magnitude of said second resistance.

In the currently preferred embodiment, said first force is a linear force and said second force is a rotative force or torque, and said limb portion is constituted by a foot of said person and said activation means comprise a pedal for receiving said foot with the longitudinal dimension of said foot generally perpendicular to a transverse dimension of said pedal

Advantageously, said activation means are adapted for allowing said pedal to move to and fro along a linear path determined by said slit in said housing under the influence of said first force and for allowing said pedal to rotate to and fro around an axis generally parallel to said transverse dimension under the influence of said second force.

In the currently preferred embodiment, said activation means comprise a first endless drive element in the form of an endless chain, band, ribbon, belt or the like arranged inside said housing and extending around at least two mutually spaced first wheels or pulleys rotatably arranged in said housing, said endless drive element being attached to said pedals such that linear movement of said pedals along said slits causes rotation of said first wheels by means of said first endless drive element.

Preferably, at least one of said first wheels and/or said first endless drive element is connected to first adjustable braking or resistance means adapted and arranged so as to apply a variable braking force to said first wheel and/or said first endless drive element.

Advantageously, said pedal is pivotably mounted on a shaft located coincidental with said axis and connected to second adjustable resistance or braking means adapted and arranged so as to apply a variable braking force to said shaft.

In the currently preferred embodiment, said activation means comprise a second endless drive element in the form of an endless chain, band, ribbon, belt or the like arranged inside said housing and extending around at least two mutually spaced second wheels or pulleys rotatably arranged in said housing, said endless drive element being attached to said pedals such that rotational movement of said pedals around said axis causes rotation of said second wheels by means of said second endless drive element, and at least one of said second wheels and/or said second endless drive element is connected to second adjustable resistance or braking means adapted and arranged so as to apply a variable braking force to said second wheel and/or said second endless drive element.

Preferably, at least one first wheel is connected to a corresponding second wheel by means of third adjustable resistance or braking means adapted for braking relative movement between said at least one first wheel and said corresponding second wheel such that movement of said first endless drive element causes a rotational force to be exerted on said corresponding second wheel, the magnitude of said rotational force being determined by the braking effect of said third resistance or braking means.

Said resistance or braking means may comprise a mechanical friction brake and/or an electrical motor and/or a hydraulic motor.

So as to be able to vary the exercise programme during each stroke, during each session and from session to session, it is advantageous that the apparatus further comprises computer controlling means for controlling the power output of said electrical motor or hydraulic motor according to one or more pre-determined sequences or algorithms, and power supplying means for supplying power to said electrical motor or hydraulic motor and said to said computer controlling means.

In the currently preferred embodiment, said mechanical friction brake is arranged for braking the rotation of one of said first or second wheels and comprises a braking body, preferably a disc, having a plane surface and arranged for rotation around the axis of rotation of said wheel, said axis being perpendicular to said surface, and a braking pad or block arranged for being pressed against said surface and for movement between a first position and a second position, the distance of said pad from said axis being larger in said second position than in said first position, and

preferably a biasing means is provided for biasing said braking pad from said second position to said first position.

A further main object of the invention is to provide an exercise apparatus which has a great degree of flexibility as regards the exercise intensity and also is suited for use in various positions without any major risk that objects may be damaged by being pinched or caught by the mechanism of the apparatus.

According to the invention, this object is achieved by the exercise apparatus comprising a housing comprising an interior compartment communicating with the surroundings through one or more apertures, mechanical activation means for being activated by a certain portion of said person such as a foot or a hand, said activation means extending from the interior of said compartment to the surroundings through said one or more apertures, resistance means for exerting a resistance against a first force applied to said activation means by said person and arranged in said compartment and connected to said activation means, first varying means for varying the magnitude of said resistance, computer controlling means for controlling said first varying means for varying said resistance according to one or more sequences or algorithms, and power supplying means for supplying power to said first varying means and said computer controlling means.

Hereby, a very flexible apparatus is achieved whereby exercise of many different types may be attained by means of the variation of the resistance means according to the algorithm best suited to the needs of the person utilising the apparatus. Because of the housing communicating with the surroundings through the apertures, the risk of objects being pinched or caught in the apparatus is greatly reduced.

In connection with children or weak, paralysed or handicapped persons or for other reasons it is often desirable that even more features be available for exercising.

According to the invention this is achieved by the exercise apparatus further comprising force exertion means for exerting a second force on said activation means such that said activation means may transmit said second force to said portion of said person connected to said activation means and second varying means for varying the magnitude of said second force, said computer controlling means being adapted for

controlling said second varying means for varying said second force according to one or more sequences or algorithms.

Hereby, limbs too weak to move the activation means may be exercised by the apparatus exerting a force on the limbs in question, perhaps only under a certain phase of the exercise cyclus or during the whole cyclus. This may be of use also after operations where it is necessary to move legs and arms so as to avoid blood clots even though the operated person is unconscious or unable to move the limbs in question for some other reason.

In the currently preferred embodiment of the exercise apparatus according to the invention, the resistance means comprise an electrical generator connected to said activation means such that movement of said activation means rotates said electrical generator. Hereby a simple and easily controlled resistance is available for varying the exercise programme.

Alternatively or additionally, the resistance means may comprise a hydraulic rotary motor or pump connected to said activation means such that movement of said activation means rotates said hydraulic motor or pump.

In the currently preferred embodiment of the exercise apparatus according to the invention, the force exertion means comprise an electrical motor connected to said activation means such that movement of said activation means results from rotation of said electrical motor. Hereby a simple and easily controlled activation means is available for varying the exercise programme. The electrical motor may be the same as or different from the electrical generator utilised for providing a variable resistance

Alternatively or additionally, the force exertion means may comprise a hydraulic rotary motor connected to said activation means such that movement of said activation means results from rotation of said hydraulic motor.

In the currently preferred embodiment of an exercise apparatus according to the invention, said electrical generator is connected to power uptake means for taking up electrical power generated by said generator. Hereby, the power uptake means may be controlled so as to vary the resistance provided by the electrical generator, and said power uptake means preferably comprise a variable electrical resistance, said

variable electrical resistance being adapted for being varied by said computer controlling means.

In the currently preferred embodiment of an exercise apparatus according to the invention, cooling means are provided for cooling said electrical resistance.
Hereby, build up of heat is avoided so that the apparatus does not become uncomfortably hot.

In cases where the cooling means arranged on or in the apparatus cannot function properly, for instance if the person using the apparatus is bedridden and needs to be covered by a blanket, then it is advantageous that said power uptake means comprise an electrical conduit for connecting said generator to the power mains or an external electrical energy consuming means such as a heater, a battery recharger or the like. Hereby the generated electrical power and location of the resulting heat or power dissipation is transported away from the vicinity of the apparatus.

Although the apparatus may be used for exercising many different portions of the human body, such as arm, wrist, elbow and so on, the currently preferred use is for exercising foot and/or leg muscles and joints of said person, said apertures in said housing being constituted by two slits, preferably generally rectilinear, said activation means comprising two connection members each adapted for connecting a foot receiving means with a mechanism arranged inside said compartment, each of said connection members extending through one of said slits for allowing said connection members to move in a reciprocating, preferably generally rectilinear, manner.

So as to render the apparatus comfortable to use and not prone to hooking and pinching objects in the vicinity thereof, the housing is preferably provided with a smooth, preferably resilient, surface.

So as to be able to use the exercise apparatus according to the invention in many different situations, the housing is preferably provided with fastening means for fastening attachment means for attaching the housing to a chair, a table, a bed, a wheel chair or any other means for accommodating a person utilising the apparatus, and advantageously the housing may be provided with fastening means for fastening supporting means for supporting the housing in a stable position on a horizontal surface such as a floor or a table top.

In a further aspect, the present invention relates to a brake mechanism for braking the rotation of a body, preferably for use as a braking or resistance means in an exercise apparatus according to the invention, said mechanism comprising

- a first disc and a second disc having mutually facing and spaced first planar surfaces and being mounted on a common shaft perpendicular to said surfaces, the second disc being mounted rotatable and axially displaceable with respect to said shaft,
- biasing means, preferably tension springs attached to said discs, for biasing said second disc axially towards said first disc and for biasing said second disc from a first rotational position relative to said first disc towards a second rotational position relative to said first disc,
- pairs of mutually facing and registering annular grooves provided in said first surfaces and extending concentric with said shaft, a groove of a pair in one first surface registering with the other groove of said pair in the other first surface,
- at least one sphere with a diameter larger than the maximum distance between said first surfaces received in each pair of grooves,
- the combined depth of the grooves in a pair being larger at one end of the grooves than at the other end of the grooves,
- a fixedly arranged body having a planar second surface facing and spaced from a third planar surface of said second disc parallel to and opposed to said first surface of said second disc,
- a braking pad or block arranged between said second and said third surface and displaceable between a first position at a certain distance from the axis of said shaft to a second position at a larger distance from said axis, and
- a biasing means for biasing said braking pad from said second position to said first position.

The invention will be explained more in detail in the following in connection with different embodiments of an exercise apparatus according to the invention shown solely by way of example in the accompanying drawings, wherein

Fig. 1 is a schematic perspective view of a first embodiment of an exercise apparatus according to the invention for exercising muscles, joints and tendons of the legs and/or feet,

Fig. 2 is a schematic perspective view of the exercising mechanism of the apparatus of Fig. 1,

Fig. 3 is a diagrammatic illustration of three different attachments of the foot receiving means of the exercise apparatus according to the invention,

Fig. 4 shows an enlarged scale cross section through a glider assembly of the mechanism shown in Fig. 2 ,

Fig. 5 is a schematic partly sectional view in larger scale of a detail of a second embodiment of an exercise apparatus according to the invention,

Fig. 6 is a schematic view of a further embodiment of the detail shown in Fig. 5,

Fig. 7 is a schematic perspective view of a third embodiment of an exercise apparatus according to the invention for exercising muscles, joints and tendons of the legs and/or feet,

Fig. 8 is a diagrammatic illustration of a second embodiment of an exercising mechanism for use with the embodiments of Figs. 1, 5 and 7,

Fig. 9 is a diagrammatic illustration of a third embodiment of an exercising mechanism for use with the embodiments of Figs. 1, 5 and 7,

Fig. 10 is a graph illustrating the desired development of the braking resistance applied against the forces exerted by leg muscles by a person utilizing the exercise apparatus according to the invention,

Fig. 11 is a diagrammatical elevational partly cut away view of a brake mechanism according to the invention,

Fig. 12 is a partial bottom plan view of the upper disc in Fig. 11, and

Fig. 13 is a top plan view of the lower disc in Fig. 11 seen along line A-A in Fig. 11.

Referring now to Fig. 1, a housing 1 defining an inner compartment is provided with two elongate apertures or slits 2 and 3 through which hollow rods 4 and 5, respectively extend from the compartment to the surroundings. Foot pedals 6 and 7 are pivotably mounted on the rods 4 and 5, respectively, by means of rods 8 pivotably attached to the rods 4 and 5.

The housing 1 in Fig. 1 contains the mechanism shown in Fig. 2, the rods 4 and 5 being connected to glider assemblies 9 arranged for gliding displacement along rods 10 fixedly attached to the inner wall of the housing 1 in a manner not shown, but obvious to those skilled in the art.

The glider assemblies 10 are connected to a chain 11 in a manner to be described in detail below such that the assemblies are forced to move together with the chain 11.

The chain 11 is a closed loop chain extending past and meshing with five sprocket wheels 12, 13, 14, 15 and 16 pivotably attached to the inner wall of the housing 1 in a manner not shown, but obvious to those skilled in the art.

The sprocket wheel 16 is connected to an electrical motor 17 by means of a shaft 18 such that the chain 11 may be moved by the motor 17 or movement of the chain 11 will cause the motor 17 to function as a generator. The motor 17 may be supplied with electrical power through an electrical conduit 19 having a plug 20 for being connected to the mains. The conduit 19 is connected to a switch box 21 connected to the motor 17 through electrical conduits 22 and 23.

When the motor 17 functions as a generator, an electrical resistance 24 having cooling fins is supplied with the generated electrical power through electrical conduits 22 and 23 such that the generator 17 functions as a mechanical resistance against movement of the chain 11.

A control box 25 connected to the motor 17 by an electrical conduit 26 has display fields for displaying information about the exercise programme such as work performed, time elapsed, exercise intensity and so on. In the following a more exhaustive list of possible displayed information is given. The control box 25 also contains computer controlling means for controlling the motor/generator 17 according to a desired algorithm or sequence. Data transmission means for transmitting data

from the control computer or from the display means to external computing or registration means may also be provided in the control box 25.

The glider assemblies 9 are stabilised against tilting by means of an arm 28 glidingly received in a groove or track 29 in a rod 30 attached to the inner wall of the housing 1 in a manner not shown, but obvious to those skilled in the art.

Referring now to Fig. 4 showing the cross section of glider assembly 9 in enlarged scale compared to Fig. 2, a generally square body 31 has a circular section channel 30 for glidingly receiving the rod 10 and a rectangular section channel 33 for receiving the chain 11 and a releasable attachment mechanism for attaching the body 31 to the chain. Said mechanism comprises a pin 34 arranged so as to be displaceable in a channel 35 by means of a lever 36 with a fulcrum 37, a spring 38 biasing the pin 34 towards the chain 11.

The pin 34 has a locking projection 39 that fits between two links of the chain 11 so as to lock the gliding assembly 9 in a certain position on the chain when the locking projection is inserted between two links of the chain as shown in Fig. 4.

If the lever 36 is pivoted counterclock-wise around the fulcrum 37, the locking projection 39 will be pulled out from between the two chain links against the force of the spring 38 and the assembly 9 may be moved to another position on the chain and locked in said position by releasing the lever 36 whereby the spring 38 will urge the pin 34 and projection 39 into a new locking relationship with the chain 11 in said position.

In use, a person places both feet in the pedals 6 and 7, and, in the simplest exercise programme, exercises by moving one pedal away from the person's body whereby the other pedal is moved towards said body because of the interconnection of the pedals by means of the chain 11. Hereby, the motor 17 functions as a generator and exerts a mechanical resistance against movement of the pedals and chain by the person. Said mechanical resistance is determined by the setting of the electrical resistance 24 which is controlled by the computer controlling means in the control box 25. In the simplest programme, the intensity of the mechanical resistance is constant during the entire stroke of each pedal to and fro.

A more sophisticated exercise programme may be implemented by the computer controlling means such as for instance varying the electrical resistance during the stroke of each pedal such that the resistance is lower at the start and end of a stroke, or the generator may function as a motor at certain points of the stroke to help the person perform the stroke. If one or both legs or feet of a person are paralysed, then the motor may function continuously according to a pre-set algorithm to exercise the paralysed leg or legs.

If the person utilising the apparatus has lost one leg, then the motor may help the remaining leg by pushing the respective pedal back as a replacement for the downward stroke of the missing leg. The pedal corresponding to the missing leg may then be removed.

It will be obvious to those skilled in the art that many different algorithms may be utilised for implementing different exercise programmes combining the resistance of the motor when it functions as a generator with the active help from the motor when it functions as a motor.

Although the embodiment of Fig. 9 described below is a purely mechanical embodiment, the mechanical brakes thereof may be substituted by electrical motors and may function with a computer as described above with relation to the embodiment of Fig. 2.

If a person of small stature or a child is to use the apparatus then the pedals 6 and 7 may be moved relative to the chain 11 such that the distance to the pedals and the stroke length thereof is reduced corresponding to the shorter legs of the person or child. This adaptation is performed easily and quickly by means of the lever 36 with associated release and locking mechanism shown in Fig. 4.

The outer surface of the housing 1 is made of a smooth, preferably pliant plastic material which feels comfortable to touch, and all corners are rounded to avoid abrasions during use.

The control box 25 is arranged outside the housing so as to be visible by the person using the apparatus. However, it may naturally be built into the housing in which case a transparent window is provided in the housing for viewing the display fields 27.

The housing 1 may be provided with projections or other fastening means for fastening attachment means such as straps, rods and the like for attaching the apparatus to a chair, a bed, a table, a wheel chair or the like. Further more supporting means for supporting the apparatus on a floor, a table top or the like may be attached to the housing in various manners.

The electrical motor 17 may be substituted by a rotary hydraulic motor/pump, the electrical resistance means 24 being substituted by a fluid flow resistance means.

The pedals 6 and 7 are replaceable by other types and sizes of pedals so that different exercise functions may be accommodated such as for instance pedals with straps so that the foot is held in the pedal allowing the person to pull the pedal towards the body instead of just pushing it away.

In Fig. 3 it is illustrated that the pedals 6 and 7 may be attached to the pivotable rods 8 at different points thereof such that the foot will pivot differently during a stroke of the pedal according to the location of the attachment point.

The pivoting of the pedals 6 and 7 is an important exercise of the ankle joint and of different important leg muscles, and while the simple embodiment hereof shown in Figs. 1-3 is effective for many purposes, more sophisticated exercising programmes for the ankle joint are desirable in the same manner as described above for the entire leg.

Referring now to Fig. 5, the pedal 6 is provided with a toothed rim 40 meshing with a bevel gear 41 provided at one end of a shaft 42 extending through rod 5 and at the opposite end provided with a second bevel gear 43 meshing with a crown gear 44 connected with a shaft 45 corresponding to rod in Fig. 2, but naturally pivotably and not fixedly attached to the inner surface of the housing 1. The crown gear 44 is slidingly connected to shaft 45 by means of radially inwards extending pins slidingly received in longitudinal grooves or tracks 47 in the shaft 45.

The shaft 45 is provided with a gear 48 meshing with a gear 49 on a shaft 49a of an electrical motor 50 connected to a plug 51 for electrical connection to the mains and to a control box 52 corresponding to control box 25 in Fig. 2.

In use, a pivoting of the pedal 6 around shaft 8 in the direction of the arrows R1 entails that shaft 45 will pivot in the direction of the arrows R2 and thus generate an electrical current in motor/generator 50 which will create a resistance to the pivoting movement of the pedal by means of not shown connections between the motor/generator 50 and a not shown variable electrical resistance corresponding to the resistance 24 in Fig. 2. If power is supplied to the motor 50 through plug 51 then the motor 50 will force the pedal 6 to pivot thus enabling an exercise of a wheel or paralysed ankle joint in a manner very similar to the procedure explained above in relation to Fig. 2.

Referring now to Fig. 6, a design alternative to the design of Fig. 5 with the bevelled gears 41 and 43 and gears 40 and 44 is shown comprising a chain 60 meshing with a sprocket wheel 61 on the end of shaft 8 and a sprocket wheel 62 on the end of a shaft 62a of an electrical motor 63. It will be obvious to those skilled in the art to supply the rest of the elements corresponding to the elements in Fig. 5. The chain 60 may be substituted by a double wire attached to a disc at the end of shaft 8 and at the end of shaft 62a in a manner obvious to those skilled in the art.

Referring now to Fig. 7, an exercise apparatus 70 for exercising leg and thigh muscles comprises a base plate 71 on which is mounted a housing 72 having a slit 73 in opposed lateral walls. Pedals 74 for receiving feet of a person utilizing the apparatus 70 are mounted on not shown rods that extend through the slits 73 into the housing 72 and therein are connected to an exercise mechanism according to the invention, for instance similar to the mechanism of Fig. 2 or one of the mechanisms described in the following.

Referring now to Fig. 8, an exercise mechanism designed for being installed inside a housing of an exercise apparatus according to the invention, for instance housing 72 of the Fig. 7 embodiment, is illustrated schematically as comprising an endless drive element 75 such as a chain or a plastic belt extending around four pulleys or sprocket wheels 76 rotatably mounted inside the housing 72 and two pulleys or sprocket wheels 77 rotatably mounted on an elongate slide member 78 arranged inside the housing such that it can slide to and fro in the direction of arrows R4.

The pedals 74 are suspended by means of shafts or rods 79 on carrier blocks 80 attached to the chain or belt 75 such that force exerted in the directions R4 (linear

forces) and R5 (rotational forces) on the pedals 74 by the feet of a user will move the pedals to and fro in said directions R4 and R5, respectively.

Not shown adjustable braking mechanisms are provided for applying an adjustable braking force to the wheels 76 and/or the wheels 77 and or the chain or belt 75 such that an adjustable resistance is provided against the linear forces exerted on the pedals 74. Such braking mechanisms may be purely mechanical or electrical or a combination of mechanical and electrical mechanisms (for instance such as described above with respect to Fig. 2 or below with respect to Fig. 9).

Not shown adjustable braking mechanisms are provided for applying an adjustable braking force to the shafts 79 such that an adjustable resistance is provided against the rotational forces exerted on the pedals 74. Such braking mechanisms may be purely mechanical or electrical or a combination of mechanical and electrical mechanisms (for instance such as described above with respect to Figs. 5 and 6 or below with respect to Fig. 9).

The function of the slide element 78 is to adjust the location of the path of travel and the maximum travel distance of the pedals 74 in the linear direction R4 by sliding the element 78 in the directions R3 from the middle position where the distance between the upper pair of wheels 76 and the corresponding wheel 77 is the same as the distance between the opposite lower pair of wheels 76 and the corresponding wheel 77. In this middle position of the slide element 78 the pedals 74 may travel from the uppermost wheel 76 to the opposed nethermost wheel 76, i.e. the maximum distance of pedal travel allowed by the system.

When the slide element 78 is in the uppermost position thereof adjacent the uppermost pair of wheels 76, then the pedal travel distance is at a minimum and the location of the path of travel is at the lowermost region of the system while when the slide element 78 is in its lowest position the location of the path of travel of the pedals is at the top of the system while the pedal travel distance is at a minimum. Hereby, the linear movement of the pedals 74 may be adjusted according to the requirements of the individual user according to length of legs, position relative to the exercising apparatus, inhibitions in full use of the leg muscles and so on.

Referring now to Fig. 9, an exercise mechanism similar to the one shown in Fig. 8 is combined with an additional system comprising an endless drive element and wheels or pulleys so as to coordinate the rotational forces and consequential rotational movement of the pedal with the linear forces and consequential linear movement of same. The further endless drive means such as a chain or a belt 81 is shown in dotted lines for the sake of clarity. The chain or belt 81 extends around wheels or pulleys 82 and 83 in a manner very similar to chain or belt 75 and wheels 76 and 77 described above, said description being applicable to the system shown in Fig. 9. A slide member 84 carries the wheels 83 and is by means of not shown connection elements constrained to move together with slide element 78 in the direction of the arrows R3.

The carrier block 80 to which the shaft 79 of the pedal 74 is attached is attached to a second carrier block 85 by means of a rod 86, the carrier block 85 being attached to the chain or wheel 81.

Adjustable braking elements 87 and 88 are connected to one of the lowermost pairs of wheels 76 and 82, respectively, so as to apply adjustable braking forces to the movement of the chains or belts 75 and 81, respectively. The other of the lowermost wheels 76 is connected to the other of the lowermost wheels 82 by means of a break element 89 for applying a relative braking force between the movement of said two wheels 76 and 82.

In use, the brake 87 which is constructed to apply a braking force to the wheel 76 in both directions of rotation of same, will exert a resistance against the linear force exerted by the leg muscles of a user of the apparatus while the brake 88, which also is adapted to exert a breaking force in both directions of rotation of the wheel 82 connected thereto, will exert a resistance against the rotation forces applied to the pedal 74 in both the directions of the arrows R6 by the foot of a user of the apparatus. The resistance exerted by the brake 88 is an active resistance, i.e. if the user does not exert a force to rotate the ankle, the foot will be pressed into an end position by the pedal, said end position being determined by the geometry of the pedal system and/or by the ligaments of the foot and ankle of the user. Therefore the user has to exert a force to avoid that his or her foot is rotated at the ankle by the resistance exerted by the brake 88.

The brake 89 exerts a resistance against rotation of the corresponding wheel 76 of the linear system relative to the corresponding wheel 82 of the rotational system such that if the user of the apparatus wishes to exercise the leg and foot muscles by rotating the ankle joint in the direction of the arrows R6 then the brake means 89 will exert a resistance against this rotation because such rotation will cause relative rotation of the wheels 76 and 82 interconnected by the brake means 89.

Hereby, a system of linear and rotational movement has been provided where an adjustable resistance against both linear and rotational movement of the pedal with resulting exertion of different muscles of the user's foot and leg in such a manner that many different combinations of stroke length, stroke location, necessary linear force and necessary rotational force can be achieved so as to allow development of an exercise programme for an individual user or adapting the apparatus for the needs of different users.

The brake mechanism applied may be of a purely mechanical type, for instance as described in the following with relation to Figs. 11-13, or may be of the electrical type controlled by a computer, for instance as described in connection with Figs. 2 and 5 above.

In connection with exercise, especially rehabilitative exercise, of weakened persons it is important that the resistance against the exercising force is built up to the maximum resistance gradually with a very low resistance at the start and thereafter an increasing resistance up to the maximum resistance value. This is illustrated in Fig. 10, which is a graph with the braking force BR of the brakes applied to the system or, in other words, the resistance against the movement plotted along the X-axis and the travel TR plotted along the Y-axis, the travel being either the linear travel distance or the degrees of rotational travel.

Over the first distance d1 the resistance force or braking force BR increases slowly from a low value and thereafter over the distance d2 the braking force or resistance increases gradually until reaching a maximum value max which is applied over the distance d3 whereafter the end of the linear or rotational travel has been reached and reversed whereby the resistance falls to the initial value again and the cycle is repeated.

In Fig. 10 it is illustrated that the return of the reistance or braking force BR to the initial value takes place by the system reversing direction and travelling backwards a distance d4. This will be explained more in detail in connection with the detailed discussion of Figs. 11-13 below.

Three different maximum values of the braking force are illustrated with the three curves. This is the ideal development of the braking force so that motion can be initiated against a small force which gradually builds up to the maximum. If the resistance were at the maximum from the start of the motion it would be uncomfortable and even dangerous for weakened persons to utilise the exercise apparatus according to the invention.

Referring now to Figs. 11-13, a braking mechanism 90 comprises three discs 91, 92 and 93 being circular and concentric and overlying one another. This brake 90 according to the invention is designed to provide a braking force which develops in the manner illustrated in Fig. 10. The disc 91 is maintained in a fixed position, i.e. cannot rotate and is provided with a braking pad or block 94 which is pivotably arranged for rotation in the direction of arrow R8 around a pivot 95 from a first, inactive position 94 shown in full lines to a fully activated position 94b shown in dotted lines.

A spring 96 biases the braking pad from the fully active position 94b to the inactive position 94 abutting a shaft 97 on which the discs 92 and 93 are pivotably mounted. The discs 92 and 93 are held together by spring elements 98 arranged at the periphery thereof in a circumferential groove 99. The springs 98 serve to hold the discs 92 and 93 together. The discs 92 and 93 have matching arcuate grooves 100 which extend from a large deepness to a shallower deepness in disc 93 and extend with the same deepness in disc 92.

Balls 101 are located in said grooves in the discs 92 and 93 such that they may roll or slide from one extremity of a groove to the other when the discs 92 and 93 are rotated relative to one another thereby exerting a force on the balls 101 thereby urging the balls to travel from one end of the respective groove 101 to the other end thereof.

As the grooves in disc 93 are oblique, i.e. deeper in one end and shallower at the other, rotation of disc 93 in the direction of arrow R7 and under the bias of the springs 98 will cause the balls 101 to move from the position shown in Figs. 12 and 13 to the

opposite end of the grooves 100 thereby forcing the disc 92 axially away from the disc 93 such that, as the disc 93 cannot be displaced axially in the direction away from disc 92, then disc 92 will be displaced axially towards disc 91 thereby pressing harder on the brake pad 94.

Continued rotation of disc 93 will entail that brake pad 94 will pivot in direction R8 from the inactive position 94 to the active position 94b where the moment arm of the braking force is larger thereby increasing the breaking effect of the break means 90 corresponding to the development shown in the graph in Fig. 10.

The braking force corresponding to distance d1 in Fig. 10 corresponds to the force needed to move the balls 101 from one end of the grooves 100 to the other against the force of the springs 98 while the braking force corresponding to the distance d2 in Fig. 10 corresponds to the braking effect of the brake pad 94 against the disc 92 during its travel from the inactive position 94 to the active position 94b. The braking force corresponding to distance d3 in Fig. 10 is the fully developed maximum braking force corresponding to the active position of the braking pad 94b. When the direction of rotation R7, R8 is reversed the discs 92 and 93 are separated in the direction of arrow R9 and the braking effect will be eliminated, the braking pad moving from active position 94b to inactive position 94.

When the rotational force causing rotation of discs 92 and 93 relative to one another is relieved, the disc 92 will be rotated back to the initial position because of the circumferential component of the biasing force of the springs 98 whereby the pressure on the braking pad 94b will be relieved and the pad will revert to the inactive position 94. This is illustrated by the distance d4 in Fig. 10 which is the distance traveled backwards by the disc 92.

Referring now again to Fig. 9 in connection with Figs. 11-13, braking elements 87 and 88 may each comprise two sets of discs 91-93, one set on each side of the wheel 76 and the wheel 82 with the two discs 93 of each set firmly attached to the two lateral surface of the wheels 76 and 82, respectively, and the two discs 91 of each set attached to the housing in such a manner that the discs 91 can not rotate, but can be displaced axially so as to increase or decrease the axial distance between the disc 91 and the disc 93 thereby varying the maximum pressure exerted by the corresponding

braking pad 94 on the disc 92 and thereby varying the maximum braking effect of the respective braking element.

The attachment means of the discs 91 of the brake elements 87 and 88 are adapted to be adjusted manually from outside the housing such that the user or a nursing person may adjust said axial distance between the disc 91 and the disc 93 and thus the maximum resistance against the linear and rotative movement of the pedals 74.

Hereby, braking of the wheels 76 and 88 and thereby the chains or belts 75 and 81 will take place for linear and rotative motion of the pedals in both mutually opposed directions.

The braking element 89 may also comprise two sets of discs 91-93 arranged between the corresponding pulleys or sprocket wheels 76 and 82 with the two discs 91 attached to one another and fixedly attached to the housing and with the two discs 93 fixedly attached to the wheels 76 and 82, respectively. The two wheels 76 and 82 are attached to the housing such that they can rotate and be displaced axially manually from the outside of the housing. The axial displacement of one or both of the wheels 76 and 82 will entail an increase or decrease of the axial distance between the disc 91 and the disc 93 and thereby a variation of the maximum pressure exerted by the corresponding braking pad 94 on the respective disc 92 and thereby varying the maximum braking effect of the braking element 89.

The brakes of Figs. 11-13 may also be used instead of the electrical motors 17, 50 and 63 in Figs.1, 5 and 6, respectively, to create the resistance caused by said motors when functioning as electrical generators.

Alternatively, electrical motors may substitute the brake elements 87-89 in Fig. 9 such that the embodiment of Fig. 9 may function electrically instead of purely mechanically and can generate a positive force when functioning as motors in addition to the resistance generated when functioning as generators such that the legs and ankles of the user can be activated positively.

As an important option, the apparatus according to the invention may be provided with means to register and/or display and/or electronically transmit data regarding the

operation of the apparatus such that the user and/or the health workers treating the user (patient) may evaluate different aspects of the training or rehabilitation process.

A purely mechanical apparatus according to the invention, for instance the Fig. 9 embodiment, may be provided with a counting means for counting the number of linear strokes performed and/or the number of rotative cycles performed during a given period of time or since a certain point in time or in total for the individual user. The number of strokes or tilts per time unit (speed) may also be of interest to the user or the health worker.

In embodiments having electrical resistance and activating means such as an electrical motor or hydraulic/pneumatic resistance/activating means perhaps connected to a computer many other values may be displayed or transmitted to an external registration or computer means for being analyzed and form the basis of a patient evaluation and/or a statistical analysis.

The values may be:
- number of strokes and tilts per time unit, since a certain point in time, during a certain period of time, in total for a given patient,
- maximum amount of strokes and/or tilts per time unit or per time period
-Force times distance (= work performed) during a certain time period, in total since a certain point in time or in total for a given patient,
-Force times distance divided by time(=power) as actual value or maximum.

In general, the following considerations are important in connection with a currently preferred embodiment of an exercise apparatus according to the invention:

The most effective exercise and rehabilitation of bedridden and other patients with reduced mobility is achieved by exercising the large leg muscles, and for this purpose a particular type of apparatus according to the invention, a leg press, is the currently preferred embodiment of the invention. The apparatus or leg press has been developed as three variants or types, each corresponding to a respective patient group.

The patients for whom these apparatuses are made can be divided into three groups according to their condition and needs, and the exercise which each of these three

groups can achieve has common features, but is nevertheless different on decisive points.

Thus, the three patient groups each use one of the three corresponding leg presses, the three patient groups being designated group 1, 2 and 3 and the apparatuses correspondingly type 1, 2 and 3.

The basic properties such as size, appearance and outer mode of function are identical as regards the three apparatus types. They have facilities for being secured to the mattress at the foot of the bed, on the floor in front of a chair or a wheel chair.

However, there is a difference between the inner exercising mechanism of the different types and thus a difference in their use.

The groups of patients and types of apparatuses are described below such that patient group and apparatus type are described together. Subsequently, the particular conditions concerning each patient group's use of the apparatus type are described briefly.

Patient group 1 and apparatus type 1

Patient group 1 comprises in particular ill or elderly walking-impaired people living in their own homes, nursing homes or the like. Some walking-impaired elderly people sit in a chair or lie in bed day and night and many of these elderly people are not well. Their circulative system degrades, they feel pain in the legs and their difficulty of walking increases. To get up from the chair is very exhausting and the risk of falling increases the efforts needed. Naturally, it would be best for their health to take a walk, but this is not possible for quite many elderly people.

These patients need upkeep exercise for actual strengthening of the walking function and the circulative system. Such exercise will result in upkeep or improvement of the general state of health and in improved quality of life.

It must be possible to achieve the exercise in a gentle way, but nevertheless with the necessary effect. It must be easy to cope with the difficulty in starting the exercising, and the exercising must be adapted individually both as regards the extent of the movements and the strength put into them.

Furthermore, it is important to the patients that this exercise takes place in a familiar and natural way.

Apparatus type 1 is the most simple apparatus. It is provided with two pedals formed as individually adjusted foot supports. They can be moved as a pedal stroke, i.e. in linear movement along the apparatus, and they can be tilted or rotated about an axis of rotation in the same manner as a bicycle pedal. The axis of rotation of this tilting can be displaced to lie in an arbitrary place between toes and heel and the length of the pedal stroke is adjustable.

If the stroke length is adjusted to less than the full length of the apparatus, it is possible to choose whether the pedal stroke takes place at the upper or lower end of the apparatus. If the apparatus is used in bed it will be most convenient if the pedals are nearest to the patient and if it is used on the floor by a chair, the pedals should be nearest to the floor.

The apparatus functions symmetrically as regards the two pedals both in pedal stroke and tilting. The resistance against linear pressing down of the pedals can be adjusted from zero to maximum, which is approximately 30 kg against the linear pedal stroke and a smaller torque resistance against pedal tilting or rotation.

It is possible to set the pedal system such that the apparatus requires that the foot be tilted as part of the pedal stroke cyclus.

Irrespective of the adjustment of the resistance against pedal movements, the resistance is small at the beginning of the movement and increases during the movement. This applies even though the pedal movement has stopped on the way, i.e. it is always easy to start the pedal movements.

Patient group 1 and apparatus type 1: The patient will typically be in surroundings of a familiar kind, either in his own home or in a nursing home. As the leg press must be available without great preparations, it will probably stand on the floor close to the patient's preferred chair. Both as regards appearance and mode of operation the leg press is made in such a way that it appears as an attractive piece of furniture in the patient's living room. It is easy to pull it in front of the chair and it is easy to place the legs in the foot supports of the pedals.

As the resistance against movement is always low at the beginning, it is not exhausting to get going. If the continuation of the pedal movement is too exhausting, the patient stops and continues when he is ready again.

The patient decides the speed, and the stroke length of the pedals is adjusted such that it corresponds to the patient's leg length, the height of the chair and the placement and slope of the leg press.
The cyclus can be adjusted such that either a powerful tilting of the pedal must be made before it can be pressed down or that the pedal is tilted during the pedal stroke. This ensures that the venous pump of the calf is activated.

The patient cannot fall and the avoidance of pinching injuries has been taken into consideration. It has also been anticipated that the interest of children in what is going on can lead to small fingers getting too near to the apparatus in operation. Similarly, prevention of pinching injuries in this connection have been taken into consideration.

The apparatus is provided with a counter such that the patient can keep up to date as regards the extent of the exercise. In addition, the public health service or other persons can read more data on total energy input, maximum effect etc. perhaps by means of special equipment. These data can be provided with information on points in time, as this type of information may be useful. By means of these data a more objective picture is achieved of the patient's condition as well as regarding positive or negative development of the patient since the last time read-outs were made.

The best results are obtained when the patient's perception of improved quality of life is in accordance with the measurements of his or her physical condition. In case of discrepancies nurse or physiotherapist can alter the exercise programme somewhat by adjusting the apparatus and thus achieve a more distinct development in the patient's own perception of his or her quality of life.

Patient group 2 and apparatus type 2

Patient group 2 comprises patients who have to continue rehabilitation after discharge from a hospital after disease, operation, accident, thrombus, cerebral haemorrhage etc.

The patients are in their own homes or transferred to convalescent homes or the like, and the exercise is typically aimed at reconstructing strength and condition and it is a question of supporting and preferably accelerating the recovery process

.

The rehabilitation aims at bringing the patient back to a condition as close to the previous one as possible.

Some patients in this group, for instance some aphasia patients, are one-sided paralysed persons, and for several reasons they will have a great need for exercising both legs, also the paralysed one. A quick return to a normal life depends on persistent efforts in re-training both legs. Exercise of the paralysed leg is done by means the apparatus. Thus, exercise of one-sided paralysed patients will to a great degree take place in the same way as for non-paralysed patients.

Some patients will benefit from the exercise obtained by being encountering resistance against bending the legs, i.e. pulling at the pedal. This can be combined with the general exercise performed by leg stretching, i.e. pressing down the pedal, if the press prevents leg streching until a certain pull at the other pedal is registered. Combined exercises of this kind will be particularly suitable for patients in this group.

Like the one-sided paralysed patients the one-sided leg amputees have a great need for exercise. Also for these patients it is important to get going as soon as possible. The quickly initiated exercise gives the best long-term results and for these patients it is a particular problem to get sufficiently all-round and extensive exercise.

Apparatus type 2 has some unsymmetrical functions as it is also used by one-sided paralysed or amputated persons.

It is equipped like apparatus type 1, but the return movement of a pedal can be performed by the apparatus itself. This means that exercising a one-sided paralysed patient or a person with a missing or very weak leg can take place more or less in the same way as for persons without this handicap.

Furthermore, the apparatus can be adjusted to offer a separately adjustable resistance against a pulling of one or both pedals.

Adjustments of various combinations of conditions and movements can be made such that the patient exercises as much as possible with the available muscular activity.

The apparatus is provided with a control means enabling the patient to monitor and control the exercise when assisted exercise is used, for instance for one-sided paralysed patients. The apparatus can be stopped immediately if a movement does not feel comfortable.

The measuring and registration equipment of the apparatus is more comprehensive than the equipment of apparatus type 1. Apart from data readable on the display of the apparatus, data can be read out by means of a data collection device which can be connected directly or by telephonic data transmission.

The attending physician can use some of these measurements or physiotherapist for registering the patient's condition, both in absolute terms and relative to previous measurements. This information can be used when planning the further development of the rehabilitation.

Patient group 2 and apparatus type 2: Patients in this group may be bedridden initially, typically in their own homes, and later to an increasing extent out of bed. Therefore, at the beginning of this part of the rehabilitation, the leg press will be used in bed and later by a chair, possibly a wheel chair.

As a great deal of data relating to the patient's condition is measured and registered in connection with the type 2 apparatus, the rehabilitation can be optimized considerably.

As one-sided paralysed patients are often involved, it is a particular advantage that the walking function can be retrained without risk of falling. Experience shows that exercise of the healthy leg also improves the paralysed leg. Furthermore, if the patient is able to exercise the paralysed leg, assisted by motors of the leg press, it is to be expected that the total activity involved will promote the recovery. The concentration and the efforts in this connection will probably promote the rehabilitation and as the load can be reduced it is possible to exercise and thus concentrate on the muscular activity of the legs for quite a long time without risk of overloading muscles and joints.

Patient group 3 and apparatus type 3

Patient group 3 comprises hospitalized patients beginning rehabilitation immediately after the operation.

These patients need apparatuses with a special degree of flexibility as their exercise will be hampered partly by reduced freedom of movement, partly by the fact that at the beginning there will be pain in connection with movement.

For these patients the exercise apparatus must be able to follow and assist the patient's often small improvements. Its functions must be extremely sensitive such that the patient's attempts to exercise are exploited as much as possible. This applies in

particular during the first period of time after an operation, accident or other violent incident.

After discharge from the hospital the further rehabilitation of the patient will often take place at the premises of a practising physiotherapist and accordingly as for patient group 2 in this connection. It will be possible to continue the rehabilitation as described for this group.

Apparatus type 3 is intended for all the applications mentioned in type 1 and in type 2 .

The measuring and registration equipment is more comprehensive and contains more registrations for statistical use.

This type of apparatus will form part of the further development of methods of better rehabilitation of patients after incidents that have changed the patient's mobility violently for a short or long time.

Patient group 3 and apparatus type 3: The patients are typically bedridden. Furthermore, their freedom of movement can be limited by bandages, infusion devices and the like, and under these circumstances heavy demands are made to the flexibility and the possibilites of adjustment of the leg press when in use.

The apparatus may be in the patient's bed day and night, but more probably it will mainly only be in bed when used. Of course, the patient needs help in connection with displacing the leg press, but the patient can manage the exercise itself alone. This means that exercising can take place at times where the patient is ready for it. The assistance which must rendered by others is to an extent corresponding to most other acts of the nursing and it can be rendered by anyone participating in this nursing function.

Therefore, the rehabilitation of the more active patients can be much more intense and effective than is possible with prior art exercise and rehabilitation devices and even for less active patients great improvements of the rehabilitation can be achieved by using a type 3 leg press according to the invention.